FLOOD TRENDS

Not higher but more often

Heavy precipitation has increased worldwide, but the effect of this on flood magnitude has been difficult to pinpoint. An alternative approach to analysing records shows that, in the central United States, floods have become more frequent but not larger.

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There is a widely held perception that floods are increasing around the planet. Precipitation data show significant increases in the frequency and magnitude of heavy precipitation events in many areas[1], and economic damage due to floods is on the rise[2]. Yet most analyses of flood trends do not conclusively show that the size of floods is increasing[3]. This apparent contradiction has been widely noted[4,5], and the Fifth Assessment Report of the IPCC concluded that "… there continues to be a lack of evidence and thus low confidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale"[6]. Writing in *Nature Climate Change*, Mallakpour and Villarini[7] describe an approach to detecting flood trends that may help resolve this puzzle, and use it to demonstrate widespread increases in the frequency — but not the size — of floods across parts of the central United States.

Floods have the potential to cause economic damages and loss of life: the Great Flood of 1993, for example, caused $US15 billion in damages in the Mississippi River Basin[8]. But floods also replenish reservoirs and enhance ecosystem health and are major drivers of sediment and nutrient transport. Quantifying the changing magnitude and frequency of floods is crucial to optimizing our response to them, including mapping flood hazard zones, setting flood insurance rates, designing bridges and other infrastructure such as water and wastewater treatment plants, and protecting and restoring ecosystems. Warmer air can hold more moisture, so atmospheric warming is anticipated to increase heavy precipitation events and affect flood regimes[9].

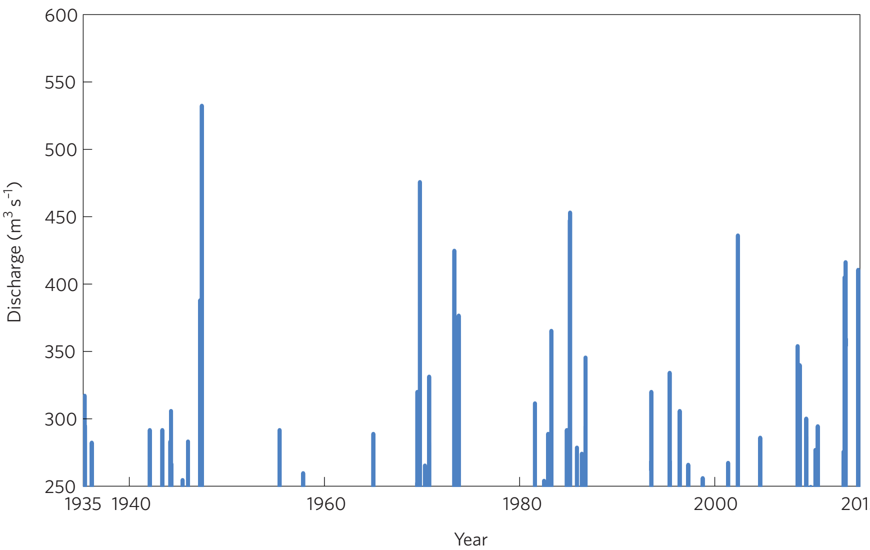

Figure 1 | Time series from one site in the central United States showing high streamflow events. The timing and magnitude of high-streamflow days (discharge of more than 250 $m^3 s^{-1}$) for the South Fabius River near Taylor, Missouri, for 1935–2014 (data from US Geological Survey) are shown. The record indicates a high degree of clustering of high-flow events with multi-year periods of no events and multi-year periods of many events. The frequency of high-flow events seems to have increased over the 60-year period, but the magnitude of the events shows no overall trend. Mallakpour and Villarini's analysis[7] of peaks-over-threshold records show that these features are common to many streamflow records across the central US.

To understand and quantify changes in flooding, hydrologists use historical observations from long-term stream gauges, which continuously measure river flow. Most analyses of flood records focus on what hydrologists term the annual peak discharge record. For example, in a 50-year record of streamflow observations, the annual peak discharge record is made up of the highest instantaneous value of discharge in each year. In a drought year, this annual peak may be so small that no one would consider calling it a flood, but it is included in the study of flood frequency and used in the evaluation of flood trends. Mallakpour and Villarini use a different approach, termed a peaks-over-threshold (POT) record, to develop a flood record from which to evaluate trends. The resulting time series registers all events in which discharge exceeded a selected high value (see Fig. 1 as an example), thus focusing only on flows that could actually be considered floods. A POT record permits analysis of changes in the frequency of flood events, which can't be done with the annual peak discharge record.

The authors evaluate trends in both the annual peak discharge and POT records from a set of 774 stream gauges in the central United States for the period 1962–2011. Their analysis of the annual peak discharge record showed no strong tendency towards increases; in fact, sites with decreases outnumbered those with increases. The POT record, however, indicated a strong tendency towards increasing flood frequency. This latter result was similar to the authors' analysis of daily rainfall statistics, which they also viewed as a time series of heavy rainfall days.

This event-based approach may prove useful in future studies aimed at explaining — or attributing — observed changes in flood patterns[10]. However, several challenges remain in characterizing this linkage. For example, the duration of heavy precipitation that produces large floods can vary substantially across different drainage basins: in very large watersheds, floods may be driven by weeks to months of heavy precipitation rather than by daily precipitation amounts. Our ability to attribute causes of flood change is further compounded by the many other factors that may affect floods in addition to the rainfall over their watersheds, including changes in land use, water storage or water management. Furthermore, variations and trends in seasonal air temperatures, particularly during spring, can affect snow and ice dynamics and drive changes in flood occurrence over cold regions. In the central US, for example, earlier springs, especially since the 1990s, may be causing more rain-on-snow events as well as lengthening the summer rainy season.

Another complexity of flood records (whether annual peaks or POT) is the role of long-term persistence, which is driven by long-term storage of moisture in soil and groundwater and by quasi-periodic oscillations of the climate system[11]. This means that when one examines long records of streamflow (over a century or more) or palaeoflood records[12], it is not uncommon to see oscillations in flood frequency or magnitude occurring on timescales of decades or even centuries. When viewed over short time periods, these records can appear to show an increasing or decreasing trend when, in fact, the observed changes are part of a natural long-term oscillation.

Improving the understanding of flood trends is an important goal for global change research. Such understanding is needed to provide an information base for adaptation to potential changes in floods and their impacts on public safety, infrastructure and ecosystems. Expanding this knowledge base will hinge on the development of innovative approaches that help model future conditions, describe trends that may have occurred so far and better relate flood behaviour to atmospheric and land-surface changes. Improved empirical characterizations of flooding trends, like those described by Mallakpour and Villarini[7], will help to evaluate the usefulness of models that are currently used to inform flood-hazard mitigation and adaptation efforts. ❐

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